Telecommunications/ transportation substitution and energy conservation

Part 1

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The substitution of telecommunications for transportation is held to have major potential for increasing energy conservation within the USA, other developed nations, and even developing nations. This article is the first of a two-part re-examination of the substitution hypothesis based on research and experience of the past decade. This part examines the theoretical potential of telecommunications–transportation substitution for energy conservation, and reviews recent research both on public attitudes towards substitution of telecommunications for travel and on the operational experience with substitution experiments in organizations. Part 2, which appears in the June 1982 issue of *Telecommunications Policy*, examines the major factors which influence whether individuals and institutions will in fact choose telecommunications over travel, and then discusses government policy which could facilitate telecommunications substitution for travel.

Keywords: Telecommunications; Transportation; Energy

The USA, as well as other developed Western countries, is increasingly characterized as an 'information society'[1] in which from 40 to 50% of the workforce is engaged in storage, transfer, or manipulation of data in 'information industries' such as banking, finance, insurance, education, the media, and government.[2] Many of the workers in these information industries travel daily to and from business centres, often in centralized business districts, to interact with other workers and with some communication or storage system, such as a computer, the mail, or a filing system. Many workers also travel from one city to another to conduct 'business meetings' (conferences, meetings, seminars) as part of their business, professional, or educational activities.

Many of the jobs and many of the business meetings do not *inherently* require face-to-face interaction or the performance of physical services necessitating a common physical location. Moreover, advances in information and communications technology provide the capability of substituting various modes of teleconferencing (computer conferencing, telephone conferencing, video conferencing) for intercity travel, and various modes of teleworking (remote computer terminals, word processing stations, teleconferencing, telecommunications-based neighbourhood work centres) for intracity travel, thereby offering the potential for substantial reductions in unnecessary face-to-face contact. Such reductions in travel, achieved throughout the information industries or some proportion thereof, could in turn have major potential for energy conservation[3] within the USA, other developed nations, and even developing nations.[4]

This highly intriguing argument has been the subject of major national and international policy discussions during the past decade.[5] It also has been the subject of technology assessments and other studies of the potential of telecommunications–transportation substitution for increasing energy conservation, and of numerous experiments with telecon-

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[1]D. Bell, 'Communications technology – for better or for worse', *Harvard Business Review*, May–June 1979, pp 20–42; S. Nora, and A. Minc, *The Computerization of Society*, MIT Press, Cambridge, MA, 1980.
[2]M.U. Porat, *The Information Economy: Definition and Measurement*, US Department of Commerce, Washington, DC, 1977.
[3]'Energy conservation' refers to energy savings resulting from greater efficiency or direct reductions in energy usage.
[4]The usual argument for substitution of telecommunications for transportation goes beyond energy conservation in the case of developing countries. The notion is that the movement of information rather than people provides a way in which developing countries, which have not yet made extensive transportation investments, can simultaneously reduce the need for energy, materials, and capital-intensive transportation systems (R.C. Harkness, and J.T. Standal, *Telecommunications Alternatives to Transportation: A Contribution to Sustainable Economic and Social Interactions*, Stanford Research Institute, Menlo Park, CA, 1976). It rests upon the critical assumption that as developing countries modernize, their workforce will undergo dramatic growth in the information sector similar to that which is occurring in developed countries, thereby creating greater demands for business travel and commuting. This assumption has not been critically examined or supported by empirical study as yet.
[5]See, for example, the final report of the National Transportation Policy Study Commission, *National Transportation Policies Through the Year 2000*,
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ferencing and teleworking in the USA, Western Europe, Japan, and Australia. Discussions, studies, and experiments carried out in the early 1970s were largely inconclusive. While they tended to demonstrate that there was theoretical potential for energy conservation through the substitution of telecommunications for transportation, they also indicated that, in reality, individual attitudes, limitations of the technology, organizational and governmental policy, the structure of cities, and cost factors operated against achieving the potential in the short term.

The purpose of this two-part article, prepared nearly ten years after these earlier discussions, studies, and experiments were started, is threefold:

- To re-examine the theoretical potential of telecommunications–transportation substitution for energy conservation.[6]
- To review recent research both on public attitudes towards substitution of telecommunications for travel and on the operational experience with substitution experiments in organizations.
- To outline the factors influencing substitution, and the public policy instruments that might be useful for increasing the likelihood that the potential of telecommunications substitution for energy conservation might be achieved.

Although reference is occasionally made to studies in other countries, the primary focus of this article is on developments, research, experience, and policy in the USA.

Methodology

This article is an original synthesis based on existing research and publications on telecommunications–transportation substitution. The major methods used in performing the study were: library search and computerized file search at the National Technical Information Service (NTIS) and the Science Information Exchange (SIE) for recent published work and ongoing research; collection and review of all published works; systematic evaluation of published works; and synthesis of findings from existing research.[7] Data were also collected on organizational experiments with teleworking. Telephone interviews were conducted with business and governmental organizations currently experimenting with various forms of telework, mainly involving computer programmers and word processing operators. The purpose was to gain preliminary information on the operational experience with these efforts so there would be some data roughly comparable to data on teleconferencing. Although by no means comprehensive, nor representative of the range of such experiments, the telephone interviews revealed that almost none of the experiments are being conducted in a systematic fashion that would yield useful results.

Telephone interviews and personal interviews were also conducted with federal, state, and local government policy makers to discuss existing and potential policy mechanisms for encouraging substitution of telecommunications for transportation. The literature on diffusion of innovations was reviewed for general policy guidance with regard to the conduct of demonstrations and experiments with new telecommunications technologies, the promotion of greater telecommunications technology use, and the introduction of new telecommunications technologies into organizations.

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Washington, DC, 1979; Richard M. Obermann, Marcel J.Zobrah and Robert S. Hentz, *Initiatives for Conserving Transportation Energy Through Telecommunications*, The MITRE Corporation, McLean, VA, 1980.

[6]Substitution of telecommunications for travel will have other impacts, such as those on working life, urban structure and form, and the transportation industry. These are not examined here except as they relate to energy conservation.

[7]The literature search revealed several interesting findings about the state of research in the field. First, the search of NTIS files revealed nearly all the important works on the telecommunications–transportation question, and the search of SIE files revealed nothing – there are currently no ongoing studies in the SIE files. While this does not mean that there are no studies ongoing, it does suggest that they must be few because the SIE files usually are an excellent source of information about research in progress. This is both an advantage and a limitation for this survey article. The advantage, confirmed by letters from other researchers in the field, is that the database for the article is indeed comprehensive. The disadvantage is that most, though not all, of the studies were conducted during the mid to late 1970s. Thus, some of the findings might be out of date. This is essentially true of the theoretical studies of potential energy savings from the substitution of tele-

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Potential for energy conservation

Telecommunications technologies of interest

There is an impressive array of telecommunications technologies and services rapidly becoming available in the USA and other Western countries (Table 1). The specific technologies of interest in the telecommunications–transportation question vary depending upon whether the object is to substitute telecommunications for meetings in person or for commuting to work and shopping. Technologies for the former purpose involve various modes of teleconferencing, whereas the latter involve various modes of office automation (supporting work at dispersed locations in satellite business centres, neighbourhood work centres, or the home) and teleshopping (shopping from home via telecommunications). The two categories are not without overlap. Many of the technologies which can be used as alternatives to meetings in person also can be used to facilitate teleworking and teleshopping.[8]

Today, there are three basic electronic alternatives to meeting in person: video, computer, and audio teleconferencing. The essential differences among these three media are the differences among visual, typewritten, and voice communication. These fundamental characteristics are not likely to change in the near future, but new capabilities will almost certainly be added which will create hybrid media between the categories. Moreover, the media probably will become more accessible as public teleconferencing services are expanded.[9] The alternatives to paper-based communication and information handling in office work are many and diverse, and can all be classed under the heading of office automation. Each of these four media – video, computer, and audio teleconferencing, and office automation – is shown in Table 2 and briefly described below.

Table 1. Classification of telecommunications technologies.

Communications	Form of signal	Established services	New services
Person-to-person	Simple code signal	Radio paging	Development of paging devices
	Voice	Standard telephone service, mobile radio and radiotelephone services	Audio teleconferencing, including loudspeaking telephone, (eg speakerphone) and multipoint telephone conferencing.
	Moving picture visual	–	Videotelephone (eg Picturephone®), video teleconferencing.
	Still image visual	Facsimile	Slow-scan video (eg for conference graphics), facsimile.
	Text	Telex/TWX	Computer message/keyboard teleconferencing systems, interconnection of word processing typewriters.
Person-to-machine	Alphanumeric (text)	Data links from teletype or VDU terminals to multi-access computers	Extensive use of computers for routine office automation including text editing, information storage and retrieval, etc.
	Computer graphics	–	
	Various	–	Telemetering and telecontrol or remote control of machines, meter reading, etc.
Machine-to-machine	Digital	Data links	Development of data networks.

Source: R.C. Harkness, *Technology Assessment of Telecommunications/Transportation Interactions*, Vol 1, Stanford Research Institute, Menlo Park, CA, 1977, Table 3, p 40.

Table 2. Telecommunication technologies usable as substitutes for activities involving transportation.

Possible substitutes for face-to-face meetings	Possible substitutes for paper-based communication and information handling	
Audio or audio-plus-graphics teleconference systems (narrowband)	Computer message systems (including computer conferencing and electronic mail)	Comprehensive office automation/communication systems
Audiovisual teleconferencing systems may include graphics capabilities (wideband)		Computer-based information systems, including document storage and retrieval Facsimile

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communications for transportation, since transportation energy usage has declined in the face of rising prices. Nevertheless, the studies reported herein are the best currently available. The problem of dated material is much less severe for studies of attitudes toward substitution of telecommunications for transportation and studies of operational experiments with telecommunications technologies. While some change has undoubtedly occurred, it probably has not been great because the basic social and technological conditions affecting user attitudes have not changed very much. Further explanation of this point is provided in Part 2.

The second finding about the state of research is that there are only a few researchers working in the field, and they are highly interconnected. While this is advantageous from many standpoints, it also introduces potential problems of bias from uncritical acceptance of assumptions, data, and forecasts. As one reviewer commented, 'the predictions about telecommunications technology and about telecommunications–transportation substitution are notoriously inaccurate, and this fact should be pointed out in the article'. Our own view is that, on balance, the better researchers have made impressive achievements given the state of current knowledge.

[8]Teleshopping is not examined in this article due to the lack of empirical studies.

[9]R. Johansen, J. Vallee, and K. Spangler, *Electronic Meetings: Technical Alternatives and Social Choices*, Addison-Wesley, Reading, MA, 1979.

[10]AT&T's Picturephone® Meeting Service currently permits video conferencing among four sites at a time, but only two groups can communicate directly with one another simultaneously: the other two can see and listen in and come up on the screen when another group goes off-line. PMS currently operates among 12 cities (New York, Pittsburgh, Boston, Philadelphia, Washington, DC, Atlanta, Detroit, Chicago, Dallas, Los Angeles, Sacramento and San Francisco), with some in colour and others in black and white.

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Video teleconferencing

Video teleconferencing uses a television-like image as well as sound for group-to-group meetings, usually involving only two groups at a time.[10] Video conference rooms are usually permanent and often elegant. The assumption behind video teleconferencing, which is usually unquestioned but has yet to be demonstrated, is that 'the closer a medium can come to face-to-face communication the better'. Johansen, Vallee and Spangler [11] point out that while video systems try to mimic face-to-face communication, it is almost impossible to eliminate the basic differences between an electronic meeting and meeting in person. Many people feel uncomfortable 'on camera': the image on a television monitor is different from face-to-face, and the studio atmosphere of some systems smacks discomfortingly of television and the movies. While they conclude that 'video conferencing appears to work for many meetings', they also note that a gnawing question remains: 'Is the full visual information always necessary for those meetings?'[12]

Video teleconferencing clearly is a technical reality, but it is complex and expensive. Complexity and cost are high because of the tremendous engineering effort required to make video images lifelike in size and quality, and because video requires 'wideband' communications to transmit the large amount of visual information involved on a continuous basis. Costs are difficult to estimate, but the *full* cost of video teleconferencing is currently about $400 per hour of usage,[13] at least five times as expensive as audio teleconferencing over comparable distances.[14] But high costs may not be the major impediment to the use of video.[15] Even at current rates, video conferencing compares favourably with travel costs, and the rates are expected to decline in the future as a result of technological improvements, such as video compression techniques, optical fibre signal transmission and efficient use of satellites.

Computer teleconferencing

Computer teleconferencing is print-based communication, usually involving 3 to 25 people who need not be present simultaneously, and who type their messages to each other on standard computer terminals linked by telephone to a computer network. Current applications range from message sending and simultaneous monitoring of crisis situations from multiple locations, to committee meetings and seminars among 'experts'. While most computer conferencing involves simple message routing, it can facilitate these broader applications through the use of other computer resources such as text editors, databases, journal systems, data

analysis packages, or models. Yet the 'strangest' feature of teleconferencing is that:

> With no images of the participants nor voices nor even a shared moment in time, a computer conference hardly seems like a 'meeting' at all.[16]

There are other drawbacks as well. Even though computer conferencing does not require skilled typing, and many conference participants get by as one-finger typists, some people never get over the discomfort of typing and others simply will not attend the conference because it requires them to type.

This problem might be solved by having someone else do the typing, in the same way a secretary types an executive's letters, but this can create its own problems. A major advantage of computer conferencing is its relatively greater accessibility, its facilitation of group communication irrespective of time and space, and its low cost. Johansen *et al* indicate that it is generally less expensive than using telephone and telex once the capital cost of the terminal itself is amortized.[17] They cite a 1975 forecast by Murray Turoff[18] that the computer portion of the cost of computer conferencing would be about $1 per hour by 1980. While they regard Turoff's forecast as optimistic, they feel that computer conferencing might be less expensive than audio teleconferencing by the mid 1980s.

Audio teleconferencing

Audio teleconferencing relies on the spoken word, and is not very different from the telephone 'conference call', with the exception that extra capacity for telecopying or telewriting is sometimes provided. The technology can be either permanent or portable, with the former consisting of specially designed (for acoustics) and equipped (table microphones, speaker cabinets, telecopying, telewriting) conference rooms, and the latter consisting of a simple portable speaker phone. The portability of audio teleconferencing and the increasing availability of public and private permanent facilities makes it the most accessible of the teleconferencing technologies. Currently, it is also the least expensive. The cost is especially low using the existing telephone network, although it increases as more people join the conference. Permanently installed systems which use dedicated lines are more expensive, although their cost can be justified if there is high use. The University of Wisconsin-Extension, which operates by audio teleconferencing at 200 sites throughout the state, estimates that its system costs about 25 cents per student per hour, not including the instructor's time.[19]

Audio conferencing seems to work especially well for regular committee meetings and for coordination meetings among members of specific projects who, while geographically separated, share a common task to be performed and have a high need to communicate with each other.[20] The major problems in audio teleconferencing are inadequate audio conditioning in conference rooms, low levels of reliability and voice quality of the audio technology, and difficulty in determining order of speaking when there are no visual cues to determine who *is* speaking, when someone is almost *finished* speaking, who is *waiting* to speak, and who should *speak next*. Technological and protocol solutions to these problems might be found, but an important question remains: can users eventually develop the same confidence in the technology for group conferencing by voice that they take for granted in one-to-one telephone calls?

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[11]Johansen, Vallee and Spangler, *op cit*, Ref 9.

[12]*Ibid*, p 8.

[13]The full cost of the video teleconferencing system between Sydney and Melbourne, Australia is about $400 per hour of usage; a comparable rate is estimated for the Japanese NTT system between Tokyo and Osaka. The Picturephone® Meeting Service is available at partially subsidized rates of $390 per hour of usage between San Francisco and New York or Washington, DC. See *ibid*.

[14]R.R. Panko, P.W. Hough, and R. Pye, 'Telecommunications for office decentralization: apparent needs and investment requirements', paper prepared for IEEE International Conference on Communications, Stanford Research Institute, Menlo Park, CA, 1976.

[15]Interviews with Australian users indicated that the costs of video teleconferencing were considered reasonable. Business clients saw cost as no problem while government users saw cost as a bureaucratic problem – teleconferencing did not fit their budget categories. (See S. Ellis, V. McKay, and M. Robinson, *Follow-up Study of Users of the Melborne-Sidney Confravision Facility*, Swinburne Institute of Technology, Australia, 1976).

[16]Johansen, Vallee and Spangler, *op cit*, Ref 9, p 11.

[17]*Ibid*.

[18]M. Turoff, 'The future of computer conferencing', *The Futurist*, Vol 9, No 4, 1975, pp 182–195.

[19]L.A. Parker, and B. Riccomini (eds), *The Status of the Telephone in Education*, University of Wisconsin-Extension Press, Madison, WI, 1976.

[20]NASA's audio conferencing system has been used in this manner. The system grew out of the need for geographically dispersed contractors and NASA sites to work together on the Apollo Project, and is the most extensive network of permanent audio conferencing facilities currently in operation. The conference sites are equipped for voice transmission and high-quality telecopying to allow immediate exchange of diagrams and technical information.

Office automation

Office automation refers to a host of technologies related to the handling of information and communication among organizations. It includes the use of computer technology and data communication to provide electronic filing, text editing and document preparation, message service (electronic mail), analysis and simulation, remote query, graphics, and other data handling functions for work that would normally be done in an office. The technologies involved in any one of these functions are also varied. For example, text handling is performed by electronic typewriters, stand-alone or multiple-terminal shared-logic word processors, and communicating word processors that permit documents to be transferred to one word processor from another or to and from a general-purpose computer using data communications. Some word processors also interface with various methods of displaying and/or storing text information such as automatic typesetting and computer output microfilm. The important feature of these office automation technologies is that they provide the independent-location communications infrastructure and support services essential to large-scale implementation of work-at-home, satellite business-centre, and neighbourhood work-centre schemes aimed at reducing travel to work.

Unlike teleconferencing technologies, office automation technologies are inexpensive, widely available, and technologically well developed such that their use is highly reliable and relatively easy even though problems do arise.[21] Office automation is also the most rapidly changing of the technologies, with the changes moving primarily in the direction of providing more capabilities from a single work station (or computer terminal, word processor, intelligent terminal) and towards integrating the technologies to form comprehensive office automation systems. Generally, the reception of office automation has been high, except when the managements responsible for introducing them have made obvious errors in the name of efficiency.[22]

Telecommunications v transportation in energy economics

The importance of the foregoing telecommunications technologies is that they might effectively substitute for transportation, thereby increasing energy conservation. Transportation plays a significant role in the economies of most Western nations. Some measure of its significance is provided by estimates of the proportion of energy used by the transport sector in the USA, Canada and the UK. Tyler, Katsoulis and Cook[23] estimate that the transportation sector accounts for 25% of total energy use in the USA and Canada, and 15% in the UK. Moreover, the transportation sector accounts for 54% of total petroleum use in the USA, 41% in Canada, and 30% in the UK. And in Canada, 60% of the petroleum used is for the transport of people.

Further understanding of transportation's significance in the energy economy is provided by detailed examinations of the US situation. The most extensive of these have been conducted by Harkness,[24] who indicated that 53.4% of all petroleum in the USA is used for transportation. Three major kinds of travel make up the bulk of energy usage for transportation that might be affected by telecommunications substitution. These are business travel, the journey to work, and travel for shopping, entertainment and recreation:

- *Business travel* constitutes 8% of all US travel mileage (air, rail,

[21]Richard Canning ('The coming impact of new technology', *EDP Analyzer*, Vol 19, No 1, 1981, pp 1–13) provided several illustrations of the kinds of problems that are sometimes associated with these technologies in a recent *EDP Analyzer*. For example, with regard to commercial message services: 'Consider the case of a manager who, at 11:00 am, decides to see if there are any messages waiting for him in his mail box. First he must get to his terminal (which might be easy or might be difficult, if shared with others), dial the telephone number of the data network, log in, ask for the message service, log in to the message service, and then ask for any messages. If the group among which messages are being exchanged is small, there is a fair chance that there are no messages waiting. If this is the result that occurs a good fraction of the time, the manager will soon be reluctant to even look for messages' (p 11). Other problems with message systems included garbled messages, the data network telephone number being busy, the message system computer being down, or error messages not being understood.

Canning also reported that there are support deficiencies in the case of equipment failure, insufficient user training, documentation, follow-up training, and modification of the systems to better meet user needs. For some people frequently, and for all people at one time or another, loss of human contact is a problem with the office automation technologies.

[22]An illustration of such errors is the decision of many organizations to set up word processing units rather than to decentralize the capability within the organization. While this might increase the efficiency of the typing function and load up the new equipment as heavily as possible, it often results in job-function changes that are dysfunctional for the organization as a whole, as when managers must themselves perform functions (answering simple correspondence, answering phones, filing, searching files, making reservations, etc) previously performed by their secretaries who now have been replaced by word processing operators and 'administrative secretaries' assigned to handle the work of multiple managers. See Canning, *op cit*, Ref 21.

[23]M. Tyler, M. Katsoulis and A. Cook, 'Telecommunications and energy policy', *Telecommunications Policy*, Vol 1, December 1976, pp 21–32.

[24]R.C. Harkness, 'Telecommunications substitutes for travel: a preliminary assessment of their potential for reducing urban transportation costs by altering office location pattern', PhD dissertation, Department of Civil Engineering, University of Washington, Seattle, WA, 1973, p 456.

vehicle) and hence is thought to have considerable potential for energy savings from substitution.[25]

- *Commuting*, or the journey to work, generally is considered the most energy-consumptive of all types of travel. Harkness[26] estimates that the journey to work accounts for 27% of all US vehicle mileage, 25% of fuel consumption, and 11% of the nation's petroleum consumption.
- *Travel for shopping, entertainment and recreation* actually consumes the same amount of energy as the journey to work. But it is probably less substitutable and is highly sensitive to energy prices since it is discretionary.

Given the magnitude of petroleum use for intercity and intracity travel, transportation has naturally become a focus of national and international policy concern. If telecommunications can be shown to be more energy efficient than transportation, it might offer considerable potential for energy conservation.

Energy usage comparisons

Estimates of the amount of energy that can be saved when travel is replaced by telecommunications vary, but some order-of-magnitude results have been derived. Generally, they show telecommunications to have higher energy efficiency than transportation for substitutable trips, even when the limitations of such comparisons are considered.[27]

In theory, it seems that the energy required to transport someone from, say, Los Angeles to New York, for a business meeting would be much greater than that required to conduct the same meeting by means of electronic signals. However, as several researchers point out, both transport and telecommunications require an extensive and complex infrastructure of equipment, maintenance and administration which is poorly understood at present. Therefore it is generally felt that no purely theoretical calculation of the energy required to overcome friction, for example, or to propagate a signal along a coaxial cable, will provide an adequate estimate of energy usage. Instead, studies of the real performance of the systems concerned must be conducted.[28]

Energy usage comparisons of this kind have been performed by Katsoulis[29] for Bell Canada, and by Pye, Tyler and Cartwright[30] for the Long Range Studies Division of Post Office Telecommunications in the UK. The methods used are similar,[31] and the results point to essentially the same findings. Katsoulis[32] compared the energy usage for several modes of telecommunication and transportation among four Canadian cities (Quebec, Toronto, Montreal, and Ottawa) for meetings of varying duration among four people, two of whom would travel. He found considerable energy savings from the substitution of telecommunications for transportation, with energy efficiency increasing when the duration of the meetings is shorter and when the mode of transportation compared is automobile or airplane rather than rail.

Pye, Tyler and Cartwright[33] examined travel among four UK cities. They examined the comparative energy usage of three modes of telecommunications (studio-based audio system, viewphone and Confravision) and three modes of transportation (rail, air and car) for a three-hour meeting involving four people, two of whom would travel between London, Glasgow, Manchester and Birmingham. They found that with telecommunications substitution, energy conservation increased with the distance between cities, the number of people involved in the meetings,

[25] *Ibid*, pp 456 ff.
[26] *Ibid*, pp 456 ff.
[27] The major limitation of these studies is that they compare energy consumption for a single teleconference with that involved in travel to an equivalent face-to-face meeting; yet long-distance business trips frequently involve several meetings. This effect is far less pronounced for the much more numerous short-distance trips.
[28] M. Tyler, B. Cartwright and H.A. Collins, *Prospects for Teleconferencing*, Intelligence Bulletin 9, Long Range Studies Division, Post Office Telecommunications, London, 1977; M. Tyler, M. Katsoulis, and A. Cook, 'Telecommunications and energy policy', *Telecommunications Policy*, Vol 1, No 1, December 1976, pp 21–32; M. Tyler, M. Elton, and A. Cook, *The Contribution of Telecommunications to the Conservation of Energy Resources*, OT Special Publication 77–17, Office of Telecommunications, US Department of Commerce, Washington DC, 1977.
[29] M. Katsoulis, *Travel/Telecommunications Substitution – Its Potential for Energy Conservation in Canada*, Bell Canada, Montreal, 1976.
[30] R. Pye, M. Tyler, and B. Cartwright, 'Telecommunicate or travel', *New Scientist*, Vol 63, No 514, 1974, pp 641–644.
[31] Both the UK and Canadian studies used essentially the same conceptual basis. They distinguished between direct and indirect energy use, between average and marginal rates of energy use, and between the energy dissipated by the system under consideration, and the primary energy input used. The results summarized are for direct energy consumption and do not include energy embodied in goods or services consumed by the telecommunications systems. They do, however, account for all the primary energy input used in supplying the system's direct energy needs. The estimates of potential energy savings from substitution are also associated with an increment of traffic. They assume that the system capacity is adjusted proportionately to such changes in traffic and that overhead energy consumption by administrative or maintenance functions in the telecommunications and transportation organizations will not increase proportionately but are fixed overhead (Tyler, Katsoulis and Cook, *op cit*, Ref 23, p 23).
[32] *Op cit*, Ref 29.
[33] *Op cit*, Ref 30.

and the shorter duration of meetings. On the London–Glasgow link, which was the longest and is comparable to the Montreal–Toronto link studied by Katsoulis, they found that the substitution of telecommunications for transportation resulted in a 20% energy saving.

Potential magnitude of energy savings

While the foregoing comparisons suggest that telecommunications is more efficient than transportation in terms of energy usage, by themselves they do not provide an overall estimate of energy savings from substitution. Attempts to develop such an estimate have focused on (a) determining what share of the present or future volume of face-to-face communication could involve telecommunications rather than travel; (b) estimating what proportion of total travel such substitution could provide; and (c) calculating the resultant savings to total transportation energy and total national energy.

Although most writers have not been willing to make such overall estimates, because of the many problematic assumptions and the poor data sources available, Katsoulis,[34] and Tyler, Katsoulis and Cook[35] have made 'cautious' estimates. Basically, they have done so in the following manner:

- They used data from the Kollen and Garwood[36] survey of the attitudes of 9619 business travellers, who were presented with hypothetical telecommunications alternatives and asked their views as to whether their trips could be substituted by telecommunications. The survey indicated that 20% of the reported trips would not have been made had an acceptable telecommunications alternative been available.
- They also used data from the Kollen and Garwood study to determine what proportion of total business travel is travel to meetings. The study indicated that this proportion is about 75%. Thus, based upon these two proportions, the substitution potential of telecommunications for all business travel would be about 28% of the total. They indicated that these results converged with the results of demand-modelling studies, which indicated a substitution potential of just about 25% of total business travel.[37]
- They then calculated the energy savings realizable from substitution for intercity business travel, assuming that the substitution would occur on the scale envisaged above and that 'the policy environment (in terms of prices and budgeting for energy and travel) is such as to stimulate substitution and minimize generation effects'. Katsoulis's estimate of the savings that could be realized by telecommunications substitution for Canadian intercity business travel was 3% of the total energy consumption by the transport sector in Canada, 1.3% of total energy use.
- They then argued that to this must be added 'an allowance of direct trip substitution likely to occur within metropolitan areas'. Although no reliable estimates of intracity substitution impacts of telecommunications are available, they indicated that 'rough estimates made in the UK suggest that the energy savings may be on the same scale as the savings achievable in intercity travel.[38]
- Finally, based on the foregoing assumptions, data and estimates about energy savings, they concluded that 'it does not seem unreasonable to suppose that the overall total may be in the range of

[34] *Op cit*, Ref 29.
[35] *Op cit*, Ref 23.
[36] J.H. Kollen, and J. Garwood, *Travel/Telecommunications Tradeoff: The Potential for Substitution Among Business Travelers*, Bell Canada, Montreal, 1975.
[37] Tyler, Cartwright and Collins, *op cit*, Ref 28.
[38] Tyler, Katsoulis and Cook, *op cit*, p 30.

one to three percent of total energy consumption, or up to five percent of petroleum consumption, depending on national conditions'.[39]

By far, the most extensive estimate of energy savings from telecommunications–transportation substitution has been made by Harkness[40] in the form of a 'technology assessment'. The basic approach of the study was to generate a set of two intercity and four urban scenarios that embody various ways in which the interactions between telecommuncations and transportation might change, and then to assess, among other things, their energy consequences. The scenarios, which were designed to be technically and otherwise feasible in the light of current knowledge, were analysed on a 'what if' basis. Three types of scenarios were involved:

1. Use of two-way audio or audio-video teleconferencing systems as a substitute for face-to-face business meetings and thus business travel.
2. An increased rate of office decentralization from major central business districts to suburban locations, resulting in part from teleconferencing and other telecommunications improvements that make physical agglomerations less necessary.
3. Use of teleconferencing plus 'office automation' (as a replacement for paper-based information) technology to allow office workers to work at or near home.[40]

Based upon systems analysis of these three scenarios, Harkness[41] concluded:

Twenty percent reduction in business air travel could save about 80000 barrels of jet fuel daily in 1985 while the same reduction in business travel by auto would save 110000 barrels of gasoline daily. If 50 percent of all US office employees worked in neighbourhood office centers six out of every seven working days, the saving potential from reduced commuting is roughly 240000 barrels daily in 1985.

Figure 1, taken from the Harkness study, shows how these savings compare with other conservation measures identified by the Federal Energy Administration (FEA). It is interesting to note that the FEA estimates that every 100000 barrels per day in savings justifies a capital investment of about $8.6 billion. Thus, taken together, the above measures could justify a $37 billion investment in telecommunications substitution alone. Additional investment could be justified by savings in highway construction, mass transit construction and operation, airport expansion, and aeroplane development.

These estimates suggest that there is indeed potential for increasing energy conservation from the greater use of telecommunications in place of travel, although the potential savings are much less than many people had earlier thought they might be. Moreover, these estimates rest upon behaviour and cost assumptions which, while reasonable in the light of existing research, may or may not hold true in the future. Some indications of the behavioural factors involved in the substitution question can be seen by review of existing research on teleconferencing and teleworking.

Teleconferencing substitution for intercity travel

The urge to travel and see the world with one's own eyes will probably be enhanced, not lessened, by the availability of instant, personal picture communications; but the need for many ordinary trips for shopping, for

[39] *Ibid*, p 30.
[40] R.C. Harkness, *Technology Assessment of Telecommunications/Transportation Interactions*, Vol I and Vol II, Stanford Research Institute, Menlo Park, CA, 1977.
[41] *Ibid*, p 111.

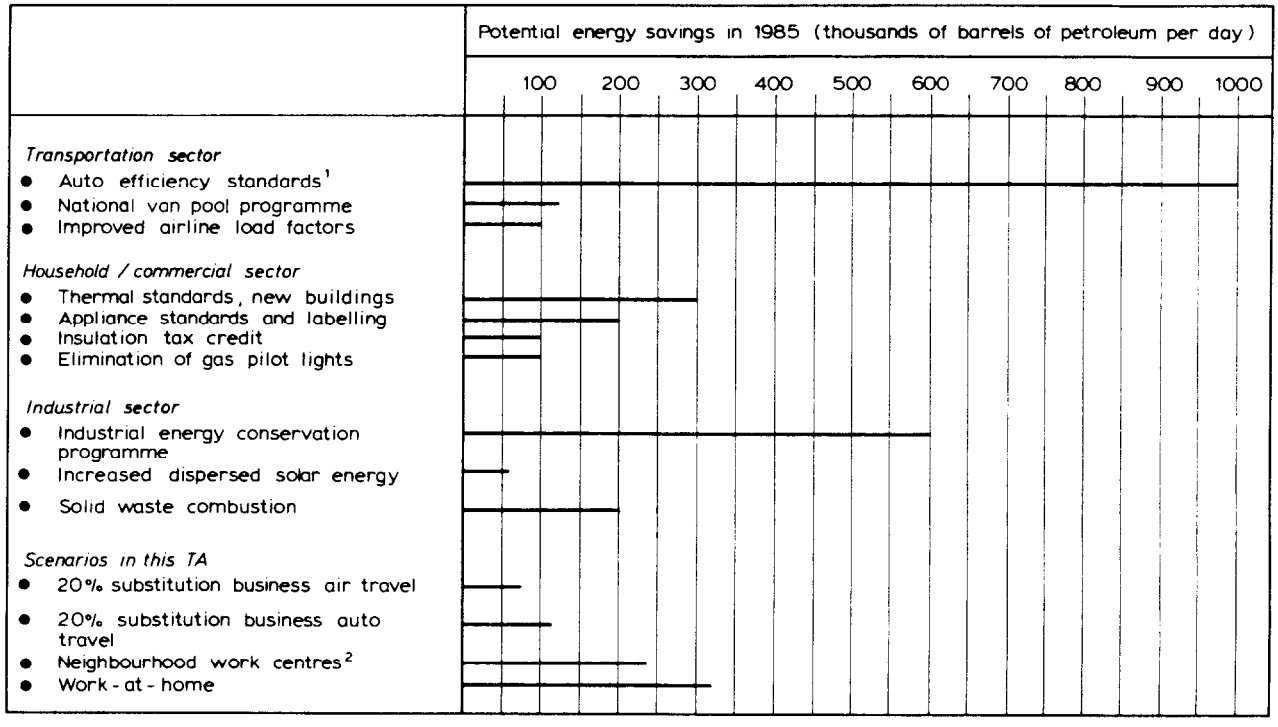

Figure 1. Harkness's estimates of energy savings of telecommunications substitution scenarios related to other energy conservation concepts.
[a]27.5 m/g in 1985 models; [b]these are not additive.
Source: R.C. Harkness, *Technology Assessment of Telecommunications/Transportation Interactions*, Vol 1, Stanford Research Institute, Menlo Park, CA, 1977, p 112.

conducting normal business, and for some social purposes should be greatly reduced. As a result, there will be less need for dense population centers. We can even hope to see an end to the continuing increase in city traffic jams. . .[42]

What actually happens when new technologies are introduced into society is partly a function of such visionary concepts. But effects are also influenced by the realities of what is technologically, economically, and behaviourally feasible and practical. While there appears to be no question as to whether telecommunications advances, such as teleconferencing, *can* be used as a substitute for some intercity travel, especially for some proportion of business travel, two key questions arise with regard to this prospect. Will the effectiveness and acceptability of teleconferencing be such that it will be accepted as a replacement for face-to-face meetings? If teleconferencing is accepted on a large scale will the net effect on transportation be to reduce, or to stimulate, demand for travel?

Substitutability of teleconferencing for face-to-face meetings

A number of theoretical studies have been conducted in an effort to predict the percentage and type of business trips that might be substituted by teleconferencing systems. These studies tend to be of two types: demand modelling studies and attitude surveys of business travellers. In addition, a number of operational studies of actual experiences with the use of teleconferencing have been conducted. The findings from these studies are reviewed next.

Demand modelling. Travel and telecommunications demand models have been constructed by the Long Range Studies Division (LRS) of British

[42]J.P. Molnar, 'Picturephone service – a new way of communicating', *Bell Laboratories Record*, Vol 47, No 5, May/June, 1969.

Telecom, and are similar in concept to the transportation modal-split models used to estimate the relative use of automobile and mass transit. The models simulate the future split of total 'interactive business communication activity' between competing travel and telecommunications media. The results of these modelling efforts indicate the *upper potential* for substitution because they consider only the effectiveness of various models of teleconferencing versus face-to-face meetings. On this basis, the LRS models indicate that 41% of all trips to business meetings (based on trip data from a stratified sample of about 1000 business meetings in the UK and 'assumed year 2000 conditions') could have been substituted by the narrowband teleconferencing devices without loss (or gain) in the effectiveness with which participants could communicate with each other. The addition of a video capability would accommodate another 9%.[43] These estimates apply only to travel to business meetings rather than to total business travel. However, as indicated earlier, data from studies in the UK and Canada indicate that about 75% of intercity business travel is to meetings. Therefore, the LRS results for substitution of business travel imply a saturation level of between 25 and 30% by the year 2000.

Attitude studies. Research on the attitudes of business travellers towards travel and the use of telecommunications constitutes the bulk of research on the substitution of teleconferencing for transportation and on the telecommunications–transportation question generally. The major studies, and their specific findings regarding various issues in the substitution questions, are summarized in Table 3. The quality of the studies reported there varies considerably due to problems of sample size, research bias, and quality of research procedures and instruments. Nevertheless, some general conclusions can be drawn from the better studies. Interested readers are urged to examine the specific findings in Table 3 as well as in two excellent reviews of the various studies by Gold[44] and Cordell and Stinson.[45] The general conclusions from the studies can be summarized as follows:

- Business travellers generally seem satisfied with the frequency of their travel.
- Most business travellers feel that they *need/desire* to keep their frequency of business travel at the same rate, or increase it.
- Most business travellers find some personal aspects of business trips to be as important as business aspects; but non-business aspects do not appear to be sufficiently important to enter into the decision making process that determines whether or not a trip is taken.
- The desire of business travellers to *decrease travel* is directly related to the rate at which an individual travels.
- Most business travel (75%) is to business meetings.
- Most business travellers attend meetings where the primary activity is one which theory and laboratory experiments have suggested is easily substituted for by teleconferencing media. In particular, they attend meetings which theoretically have high substitutability by audio or facsimile media.
- Most business travellers feel that they could not substitute teleconferencing for travel generally, or for their most recent trip.
- Business travellers are prone to select audio and facsimile media rather than video and computer media as teleconferencing media to substitute for their travel.

[43]Harkness, *op cit*, Ref 40, p 50. The modelling effort did not account for possible 'generation' effects, did not take into account the importance of non-work-related considerations in choice of travel versus telecommunications medium, and was not calibrated using data on real travel and telecommunications choices (since suitable databases do not yet exist) (*ibid*, p 153).

[44]E.M. Gold, 'Attitudes to intercity travel substitution', *Telecommunications Policy*, Vol 4, No 2, June 1979, pp 88–104.

[45]A.J. Cordell, and J. Stinson, 'Travel and telecommunications: survey results to date and future possibilities', background paper prepared for the Science Council Committee on Computers and Communications, Science Council of Canada, Ottawa, 1979.

Table 3. Summary of major findings from research on attitudes towards business travel, and/or substitution of telecommunications for intercity travel.

Study source/ description	General attitude towards travel	Non-business activities of trip	Need/desire to decrease travel	Telecommunication substitution	Substitution by mode
Westrum.[a] Doctoral dissertation; survey of about 400 plant managers and middle managers attending training programs at two US universities.	49% of the managers took 10 trips or more in a previous year. The managers were generally satisfied with the frequency of their travel; 87% felt they wanted to take the same number of, or more, business trips.	Business travellers find some personal aspects of business trips to be as important as business aspects. 78% felt that the personal aspects ('seeing things and places', 'enjoying new faces' were as 'important' as the business aspects or 'very important'.	92% felt they *needed* to take the same number or more trips than previously; 3% felt they needed to take fewer. 9% wanted to take fewer business trips. Desire to take fewer trips is directly related to the number of trips previously taken. 50% of those who took 0–4 trips in the previous year, 75% of those who took 5–9 trips, 87% of those who took 10–19 trips, and 82% of those who took 20+ trips desired to take fewer.		
Kollen & Garwood.[b] Bell Canada survey of 9619 business travellers between Montreal, Ottawa, Quebec and Toronto; considerable effort was made to give the survey the maximum feasible precision (by discussing with the respondent).	62% felt they would like to keep their frequency of business travel at the same rate or increase it.	56% participated in non-business activities (visiting relatives & friends, entertainment, etc.) during their business trips. Nonbusiness activities were not sufficiently important to enter into the decision-making process that determines whether or not a trip is taken.	37% of travellers wished to decrease the amount of travel while 15% wished to increase it. Desire to decrease travel is directly related to the rate at which an individual travels. 51% of those who travelled every other week desired to reduce travel.	The overwhelming majority (80%) of business travellers felt that their frequency of travel could not have substituted teleconferencing for their trip in particular. 20% felt they would not have taken the trip had an acceptable telecommunications alternative been available.	Business travellers were less prone to select video (58%) and computer (55%) media than audio (74%) and facsimile (75%) media as teleconferencing media to substitute for their travel. A large plurality of business travellers attended meetings where the primary activity was one for which teleconferencing media *theoretically* could be substituted. 80% of the travellers indicated that even if they had had access to teleconferencing, they still would have travelled.
Gold.[c] Jet Propulsion Laboratory surveys of about 178 JPL managers and non-managers, some of whom had used the NASA teleconferencing system available at JPL; used interview items from Bell Canada survey.			50% of JPL travellers felt they would have preferred not to have taken their last trip.	90% of JPL travellers claimed to know what teleconferencing was; over 80% were aware of the NASA system available at JPL. 5.6% of JPL travellers felt that method of teleconferencing. ferencing.	JPL travellers were about equally prone (39–43%) to select video, facsimile and audio teleconferencing media as a general substitute for travel. JPL travellers were more likely to select video teleconferencing as a substitute.
Israelski.[d] AT&T user-survey of Bell Systems Picturephone®					75% of PMS users felt it was a satisfactory substitute for travel.

Table 3 (continued). Summary of major findings from research on attitudes towards business travel, and/or substitution of telecommunications for intercity travel.

Study source/ description	General attitude towards travel	Non-business activities of trip	Need/desire to decrease travel	Telecommunication substitution	Substitution by mode
Meeting Service (PMS). Chumak.[e] OECD market study on teleconferencing.				60% of business meetings could be conducted by some form of teleconferencing, but 40% required face-to face meetings.	40% of business meetings could be conducted through audio media with complete effectiveness. 20% of the meetings required video media.
Communications Studies Group.[f] Used British civil servants as the test group.				54–72% of meetings could be carried out effectively using some form of telecommunications.	31—49% of meetings could be carried out through an audio system of communication. A video system could be considered appropriate for 23% of meetings.
Kahn.[g] Review of 'informed speculation' by a number of researchers regarding the substitutability of telecommunications for transportation.					The 'informed speculation' of experts suggests that the ultimate substitution rate of telecommunications for transportation is 18–22%.

Source: R.C. Harkness, *Technology Assessment of Telecommunications/Transportation Interactions*, Vol 1, Stanford Research Institute, Menlo Park, CA, 1977, Table 4, p 41.

[a]R.M. Westrum, 'Communication systems and social change', PhD thesis, Department of Sociology, University of Indiana, Lafayette, IN, 1972. [b]J.H. Kollen and J. Garwood, *Travel/ Telecommunications Tradeoff: The Potential for Substitution Among Business Travelers*, Bell Canada, Montreal, 1975. [c]E.M. Gold, *Teleconferencing Implications for JPL*, JPL Report 900–873, Jet Propulsion Laboratory, Pasadena, CA, 1978; E.M. Gold, *Teleconferencing Implications for JPL*, JPL Report 900–896, Jet Propulsion Laboratory, Pasadena, CA, 1978. [d]E.W. Israelski, 'A user study of the Bell Systems video teleconferencing system: applications and attitudes', *Ergonomics*, Vol 22, No 6, 1979. [e]A. Chumak, 'The potential for telecommunications as a travel substitute', Role of the Automobile Study Working Paper No 10, Strategic Planning Group, Transport Canada, January 1979. [f]Communications Studies Group, *The Effectiveness of Person-to-Person Telecommunications Systems*, Long Range Research Report 003/ITF, Post Office Telecommunications, London, May 1975. [g]A.M. Kahn, 'Travel v telecommunication: current understanding', *High Speed Ground Transportation*, Vol 10, No 3, 1976, pp 203–216.

- Managers are more prone to substitute teleconferencing for travel than are non-managers.

There is every reason to believe, based upon these findings, that business travellers will continue in their present travel patterns unless new political, economic or organizational factors stimulate them to modify their travel behaviour.[46] Moreover, although estimates of the potential rates of substitution of teleconferencing for intercity travel vary from a low of 6% to a high of 75%, the better studies seem to converge on the finding that the perceived substitutability of telecommunications for travel is about 20 to 30%. And the results vary depending upon the type of telecommunications medium offered as a substitute for travel.

Operational studies. Operational studies refer to those which examine the usage of operational teleconferencing systems. This type of study attempts to determine the extent to which an existing system has been used within an organization and the extent to which such use has reduced travel. There are relatively few teleconferencing systems operating currently, and there are relatively few studies which evaluate their actual use.

[46]One factor might be simply the wider availability of quality operational teleconferencing capabilities. For example, Harkness argues out that 'the actual adoption and fairly extensive use of teleconferencing within several large organizations [AT&T, IBM, Boeing, Aetna, and Proctor and Gamble] within the last year or two has laid to rest some of the uncertainty many of us had about its behavioural acceptability'. Harkness indicates that these systems are 'voluntary' and yet have had considerable use because they are convenient and save time. Still, better understanding of these systems is needed to determine what organizational factors are influencing current use (personal communication from Richard C. Harkness, 13 July 1981).

Gold[47] summarized and *critically evaluated* the results from the eleven functioning teleconferencing systems in North America, shown in Table 4. In two of the 11 systems, results of studies were not complete (and still are not).[48] Of the remaining nine systems, four showed actual reductions in travel, three showed reductions in travel budgets, and two showed no reduction in travel during the period of study. Based on these results, Gold concluded that:

> . . . no trend towards intercity travel reduction has been found. This is not to suggest that some organizations have not presented figures showing travel cost savings: many have done so. The evidence is that this does not indicate a reduction in travel, but is 'cost avoidance' – a measure of the cost of a trip not taken.

Gold's distinction between reductions in travel budgets (cost avoidance) and reductions in the frequency of travel is important because it articulates *two different* but highly relevant and objective indicators of substitution effects.

The operational studies to date have clearly failed to establish that telecommunications has significantly reduced travel, but it is important to remember that the studies are of technology developed in the late 1960s and early 1970s. Cordell and Stinson[49] argue that new systems, which are being produced, will yield a different outcome as regards the rate of usage:

> Acceptance will be a function of greater availability of systems hardware and therefore easier to access; rising energy costs and a desire by institutions of all types to control costs; better technology which is designed for interactive situations and a technology which takes account of 'people factors'.

Generation of travel demand by telecommunications

The answer to the second question in this section ('will telecommunications reduce or stimulate demand for travel?') seems to be 'it all depends'. Clearly, there is the possibility that any substitution effect will be wholly or partly offset by the stimulation of new travel demand. But two different approaches to answering the question seem to indicate that generated travel will generally be small. Tyler[50] used an aggregate

[47] *Op cit*, Ref 44.
[48] Personal communication with E.M. Gold.
[49] *Op cit*, Ref 45, p 6.
[50] M. Tyler, 'Developments in telecommunications: the implications for transport', Long Range Studies Division, Post Office Telecommunications, Cambridge, UK, 1976, p 22.

Table 4. Summary of operational studies of teleconferencing–travel substitution

Organization	System type	Claim
Atlantic Richfield	Audio	No reduction
Bell Canada/TCTS	Video	Report pending: points to potential of reduced travel
US Department of Energy	Video	Cost avoidance
General Services Administration	Audio	Cost avoidance
Illinois Bell	Video	Travel expenses saved
JPL	Audio	Nearly 10% reduction over 3–4 years
NASA	Audio	Cost avoidance
Union Trust	Audio	Estimated savings of auto travel
United California Bank	Audio	Travel reduced, but less than expected
Pacific Coast Stock Exchange	Portable audio	No change
Public Service Commission Ottawa	Audio	Study underway

Summary of results from operational studies	
Travel reduction achieved	4
Cost avoidance achieved	3
No travel or cost reduction achieved	2
Study underway	2

Source: Elliot M. Gold, 'Attitudes to intercity travel substitution', *Telecommunications Policy*, Vol 3, No 2, June 1979, pp 88–104.

approach which deals with the overall volumes of communication and the total amount of time and resources committed to achieve them. He noted that improved availability or cost-effectiveness of telecommunications increases demand for communication in general, and also increases the proportion of total communication activity carried by telecommunications media. The former effect tends to increase transportation traffic whereas the latter tends to decrease it. The question is, which of the two effects will be larger? Using the concept of time-budgets, Tyler argues that if telecommunications takes over a significant share of a business person's present annual schedule of meetings, saving his or her travel time and thus presenting a bonus of free time, the generation effects generally will be small. This is because 'a business communicator is unlikely to "spend" all of the time he gains . . . in additional communication – let alone spend all of it on the mode of communication (travel) whose relative attractiveness has been reduced by telecommunications developments'.[51]

However, as noted by Harkness,[52] 'even if travel-generation effects are small in the aggregate, this may not be true for all classes of trips'. He therefore examines three 'generation hypotheses' about how the surplus of time and money (or both) created by substitution of some trips by telecommunications might be spent. His results, while interesting, are inconclusive about whether the net effect of substitution is to increase or decrease travel, but he seems to feel that travel-generation effects stimulated by telecommunications ultimately would be constrained by time, money, or other factors (eg organizational policy toward travel authorizations and budgets).

'Teleworking' substitution for intracity travel

The extent to which teleworking referred to as 'telecommuting' by Nilles, *et al*,[53] and others might substitute for commuting depends upon the type of work the commuter performs. Some work 'requires the physical presence of the employee at or near an immovable object or central location', (eg the creation of physical goods in factories, the transfer of physical goods or the performance of a service requiring face-to-face meetings.[54] The key feature of such work is that it is tied to some location and is therefore heavily transportation-dependent. Most researchers agree that it is difficult to foresee alternatives to transportation for workers engaged in such industries.

However, other kinds of work do not necessarily require the physical presence of the worker at some fixed location. This is generally regarded to be the case for work that is related to the creation, transfer, processing or storage of information, ie work in the 'information industries' such as education, insurance, banking, and finance. Thus it is generally felt that many information industry workers could 'telework' – they could perform their work, using communications and computer technologies, in their homes or at locations much closer to their homes than is often the case now.

There are no reliable estimates of what percentage of the office work force might ultimately adopt teleworking. Harkness[55] indicated that 'the only available estimate, which is without strong basis, suggests that roughly half the office work force is the upper limit'.[56] At this level, he estimated that in the US 'the neighborhood office center concept could save roughly 238000 barrels of gasoline daily in 1985 or the work at home

[51] *Ibid.*
[52] *Op cit*, Ref 40, p 58.
[53] J. M. Nilles, F.R. Carlson Jr, P. Gray, and G.J. Hanneman, *The Telecommunications-Transportation Tradeoff*, John Wiley & Sons, New York, 1976.
[54] *Ibid*, p 4.
[55] *Op cit*, Ref 40, p x.
[56] Jones estimated that 22% of all jobs in the San Francisco Bay area in 1965 were of types amenable to teleworking. Corresponding figures for the City of San Francisco were 31%, and for its central business district – 47% (D.W. Jones Jr, *Must We Travel: The Potential of Communication as a Substitute for Urban Travel*, Institute for Communication Research, Report RR-5, Stanford University, Stanford, CA, March 1973).

scenario could save 320000 barrels per day. This amounts to 1.02 and 1.40%, respectively, of total estimated 1985 petroleum consumption (these are not, of course, additive)'.

Substitutability of office automation for commuting

The major categories of work in the information industries that are thought to be most susceptible to teleworking are the managerial, professional and clerical levels involving, for example, various kinds of managers, information analysts, computer professionals, and information or word processing clerks. Indeed, several studies have concluded that a large number of managerial, clerical, and professional functions *could* be performed by using various modes of telecommunications, provided that certain additional criteria were met. For example, Reid[57] concluded that a large number of management functions could be performed effectively using telephone bandwidth communications, provided two criteria were met: (a) that the participants in the communication process know each other and are familiar with the contextual clues about each other's attitudes and emotions (this also implies that face-to-face meetings must be held and repeated occasionally); and (b) that some form of contextual or graphic display is provided in addition to the teleconferencing capability.

These and other studies have concluded that teleworking is cost-beneficial from individual, organizational, and urban-metropolitan perspectives. For example, Nilles *et al*[58] reported that:

> Instructional television as a telecommunication substitute for transportation offers the IITV user a substantial savings in time and travel. The director of the IITV system at USC, Dr Jack Munushian, estimated that in its first two years of operation, the USC IITV system saved 250000 commuter miles.

These potential cost and energy savings have led Nilles to predict that 'up to 10 million workers will be telecommuting by the mid 1990s'.[59] Whether such optimistic predictions are warranted is questionable.[60] Clearly, however, there are cost and energy savings to be achieved by increased use of teleworking particularly when viewed from an organizational and urban-metropolitan perspective. Moreover, to the extent that the time spent in commuting increases and the cost of energy also increases, one might expect that the savings to individuals could become sizable enough to encourage substitution of teleworking for travel to work among those who are able to seriously consider it.

The key question, however, is *whether individuals perceive teleworking as cost-beneficial to themselves* and, hence, whether they would be willing to substitute some form of teleworking for travel to work. A similar question arises with respect to the attitudes and behaviours of government and corporate managers: to what extent do managers perceive teleworking as cost-beneficial to the organization and, on that basis, would they be willing to permit or encourage their employees to use some form of teleworking or telecommunications-based neighbourhood centre in place of travelling to a central work location? A related question, independent of attitudes, is: to what extent do individuals and organizations actually substitute teleworking for travel?

As in the case of teleconferencing, two kinds of studies have been conducted to examine the substitution hypothesis with respect to teleworking: attitudinal studies and operational studies. The findings from each will be reviewed next.

[57] A. Reid, *Electronic Person-to-Person Communications*, University College, Communications Study Group, London,
[58] *Op cit*, Ref 53, p 120.
[59] *Business Week*, 'The potential for telecommuting', 26 January 1981, pp 94, 98, 103.
[60] In a personal communication, Nilles pointed out that his prediction was based upon a number of assumptions not reported in the *Business Week* article which significantly qualify the prediction. Chief among these were that the cost of energy would continue to rise as it had in the mid 1970s, that the cost of telecommunications would continue to decline at the rate it had during the 1970s, and that organizational managers would increasingly 'internalize' the costs of commuting as a factor in worker productivity.

Attitude studies. Research on commuters' perceptions of the substitutability of telecommunications for travel, and on the perceived effectiveness of such substitution, fall into the category of attitude studies. A variety of researchers have asked, if teleworking capabilities were made available to commuters, what would be their attitude toward using them for work and communication in the place of travel? A potential problem with most of these studies is that they have assumed the most favourable situation in which to consider substitutability – that in which telecommunications substitutes do not involve a one-for-one functional task substitute or require considerable retraining or re-education.[61] Nevertheless, the studies provide some useful indications.

The most extensive attitude studies of teleworking have been conducted by Nilles and his colleagues at USC, but even these are limited by their sample size and choice of respondents. The USC group conducted five surveys as follows:

- An area-wide random probability sample of Los Angeles County adult residents via telephone interviews with 197 respondents.
- A sample of the USC population of enrolled Interactive Instructional Television (IITV) students using remote classrooms in their place of employment. These respondents were primarily professionals in engineering, aerospace and information sciences taking graduate-level education during released time.
- A sample of Stanford IITV students similar in characteristics to the USC group.
- A group of night USC commuter students similar in characteristics to the IITV groups.
- A sample of regular daytime undergraduate students enrolled at USC.

In summarizing the results of these studies, the respondents are divided into users and non-users of IITV, and the Los Angeles County sample.

Users of IITV. The IITV system at USC and Stanford is a television-based system which allows some modes of visual and oral communication – such as computer conferencing – which are not available on other types of communications systems, while making other models such as data look-up and text-editing more difficult. Nevertheless, the researchers felt that the attitudes of the users toward the IITV systems might not be materially different from the attitudes of clerical trainees toward a computer terminal system (a questionable assumption). The following conclusions were drawn from the survey of users of IITV:

- The major motivation for participation in IITV is a desire on the part of the participants to complete or expand their education or training.
- Users of the IITV system showed greater affinity for this mode of education over time, suggesting that familiarity with the system could favourably affect attitudes toward the system.
- Over 60% of the participants perceived IITV as being as effective as in-the-classroom education.
- Convenience and ease of use was a key factor in the willingness of participants to make the telecommuting/transportation tradeoff.
- About 60% of the participants indicated they would be willing to pay the cost of driving their car for the IITV service and 24% were willing

[61] As Nilles *et al* (*op cit*, Ref 53, p 111) point out, substitutions involving more complex work-technology linkages are likely to be threatening to individual employees and may create problems with pay scales, union contracts, etc. Consequently, worker resistance might be high.

to pay 50% more than the cost of operating their car for the IITV service.

Non-users of IITV. The non-user surveys were designed to assess the attitudes of people who were unfamiliar with computer and communications technologies toward telecommunications as a substitute for transportation. The objective was 'to get some estimate of the predisposition of the entry level information industry workers toward, or against, telecommuting'. Since the non-users included professionals in engineering, aerospace, and information sciences who were pursuing graduate degrees, as well as undergraduates, it is questionable whether this group really represents the predisposition of 'entry level information industry workers'. However, since the results for each group can be reported separately, they are nevertheless useful. The conclusions from the survey of non-users of IITV were as follows:

- The students who travelled the most were the least receptive to alternative forms of education delivery such as IITV.
- The primary reasons for their preferring to commute to campus were their preference for the campus environment and the interaction permitted by that environment, and, in some cases, the need to be on campus for part-time work.
- The part-time evening students, who had the highest average commuting distance of all groups sampled, were more receptive to IITV, with 36% indicating that they would use IITV at work and 46% indicating they would use IITV at home. Those who had a negative response to telecommuting again cited preference for the campus environment and interactions.

General population attitudes. The conclusions from the survey of Los Angeles-area adult population attitudes toward telecommunications substitutions for transportation to their jobs were as follows:

- Respondents were about evenly split regarding their willingness to work closer to home via telecommunications links, with about 51% indicating they were not willing.
- Respondents who were most receptive to telecommuting tended to commute the greatest amount and perceived their time as being more important than those who were not receptive to telecommuting.
- Most respondents preferred working closer to their homes but not in them.
- The majority of respondents would pay nothing additional per month for telecommuting, perceiving it as a fiscal responsibility of their employers.
- The overall attitudes of respondents toward commuting were positive or showed acceptance of commuting as a necessary evil.

The USC group also concluded from their surveys that the general public 'does not really fully comprehend the potential or operation of pending telecommunications developments'.

Taken together, the USC studies suggest that most commuters generally are not very willing to substitute various modes of telecommunications for travel to work or school. Those who appear willing to do so place several conditions on their willingness: that teleworking will be easy and convenient; that the cost to them be little or nothing; and that telecommunications-based working locations be closer to home, but not in the home. Since commuters generally view travel to

work as a necessary part of their job and are generally positive towards it, or view it s a necessary evil, it seems unlikely that commuters will readily choose, on their own, to substitute telecommunications for travel to work or school. A primary reason for their unwillingness is that commuters view work and school as having positive values in terms of social interaction and the general nature of the work/school environment.

Operational studies. The popular literature is full of descriptions of operational experiments with teleworking. For example, recent *Business Week* (26 January 1981) and *New York Times* (12 March 1981) articles cited a variety of business and industry experiments with the phenomenon:

- Control Data Corporation is engaged in a project called 'work station' involving 60 professional and managerial employees in voluntary work-at-home.
- Walgreen, McDonald's, and Mountain States Telephone and Telegraph are reportedly installing terminals in the homes of handicapped employees so that they can write computer programs without having to leave their homes.
- Continental Illinois National Bank and Trust Company of Chicago reportedly has been trying teleworking with word processor operators for two years in an effort to deal with the worsening shortage of secretaries and word processing personnel.
- Freight Data Systems of Inglewood, California, which provides computer time-sharing services and application packages for the freight industry, put computer terminals in the homes of computer programmers to reduce the need for additional office space.
- F. International Ltd, a British computer software company with 600 employees, 'has almost all of its employees working at home and about half use computer terminals'.

As noted by Margrethe Olson,[62] most of these experiments can be encompassed within four major remote work options, any of which might involve substantial telecommunications support. These options are: satellite work centres, neighbourhood work centres, flexible work arrangements and work at home. Satellite work centres involve the notion that a relatively self-contained organizational division, of some minimum size to achieve economies of scale in support services and equipment (eg 100–200 people), be physically relocated within convenient commuting distance of employees. Neighbourhood work centres involve employees from different organizations sharing space and equipment in a work centre close to their homes. Flexible work arrangements involve part-time work at home, as when 'employees are encouraged to take terminals home with them at night or on weekends to accomplish critical work at "non-peak" computer hours, or just for convenience so they do not have to make an extra trip to the office to perform necessary overtime work'.[63] Work at home involves employees working at home on a regular basis.

We contacted several organizations with such arrangements supported by telecommunications to discern whether there were systematic studies available which assessed their experience. Not one of the organizations contacted was able to provide us with a comprehensive report evaluating the telework experiments – either because such evaluations were not being conducted, or because the results were not yet in.[64] Conse-

[62]M.H. Olson, *Remote Office Work: Implications for Individuals and Organizations*', Center for Research on Information Systems, Graduate School of Business Administration, New York University, 1981.
[63]*Ibid*, pp 10–11.
[64]Control Data Corporation is conducting a more or less systematic study, but the results are not yet available. A preliminary report on the experiment is contained in R.A. Manning, 'Alternate work sites', text of a speech delivered at the National Transportation Conference, Washington, DC, January 1981.

quently, we tried to obtain information from telephone interviews with individuals in various organizations regarding the organization's experience. We also used the results of the exploratory research on remote work by Olson.[65] Our investigation, and that of Olson, revealed there are important differences in the teleworking experience depending upon the nature of the telework option, the nature of the job, and the nature of the individual's personal situation. Nevertheless, the following generalizations seem warranted.[66]

(1) The single largest group of workers currently affected by teleworking are computer programmers, data entry clerks, and word processing operators – people who have understanding of and familiarity with the technology.

(2) The number of workers involved in teleworking in any organization is a small proportion of the organization's total workforce, or even of that portion of the workforce most suited to telework.

(3) The major disadvantage of teleworking from the standpoint of workers is the loss of social and/or professional interaction with other workers. Clearly the extent of social or professional isolation varies with the kind of telework arrangement, with it being greatest under work *at home* options and least with work *near home* options.[67] Some individuals do not mind the social or professional isolation. A few individuals prefer to work alone. But most workers involved in teleworking, who have other feasible alternatives, do mind the loss of interaction and would prefer their old work arrangement or some new arrangement permitting closer interaction with fellow workers. As a result, some workers have returned to 'central' office work. A related disadvantage of telework is lack of visibility for promotion among peers and managers. This disadvantage is usually limited to individuals involved as members of an organization rather than 'contract' or 'piece' workers. Most current teleworkers are the former.

(4) The major advantages to individuals are flexibility in their working hours and location, reduced commuting time and cost, and ability to meet demands of personal situations. The latter can be especially important. For example, for the handicapped and those with family responsibilities, the advantage of being able to work at all is viewed as a reasonable tradeoff to social and/or professional isolation.

(5) The major advantages to organizations involved in teleworking are several:

- Increased work productivity; at least of the order of 10% and potentially much higher. Olson[68] and Manning [69] indicate that workers report productivity increases around 100%.
- Ability to hire people who will work for less.
- Ability to hire high quality or highly skilled people in a competitive market, when location and flexible work arrangements are important factors to potential employees.
- Ability to hire people who would not otherwise be able to work in the industry (eg the handicapped and single parents of young children) and who, by virtue of their inherent motivation or gratitude for being able to work, are likely to be highly productive workers.
- Reduced need for space to house office workers, and for heating and cooling of space.
- Shift of certain costs to the workers and others; eg the organization does not have to pay for employee downtime (eg due to equipment breakdowns), office space, or utilities. In contract and piece work,

[65] *Op cit*, Ref 62.

[66] It is important to point out that Olson's exploratory research was focused on 'remote work', whether it involved a substantial telecommunications component or not. Our interviews focused only on organizations involving 'telework'. The generalizations below attempt to factor out only the findings related to telework from both investigations. Readers interested in the broader issues of remote work should refer to Olson's full report.

[67] Both Richard Harkness and Margrethe Olson point out that there is a critical distinction between working *at home* versus *near home* in neighbourhood or satellite work centres, and argue that many of the disadvantages for managers and workers do not apply to working near home to the same extent as to working at home. For example, a neighbourhood or satellite work centre provides for greater social or professional interaction with work associates than does work at home. However, work near home presents its own special set of problems for workers and managers. For example, both Manning (*op cit*, Ref 64) and T. Ottman (telephone conversation, 24 March 1981) report that even with decentralized office arrangements, central managers still have difficulty in knowing what to expect in terms of worker output, and can find the decentralized offices disconcerting because they reduce the manager's ability to visually monitor worker activity. This in turn can generate mutual distrust over issues of worker productivity. Also, while there is greater social and professional interaction for workers at the decentralized offices, it is not the same as being at the central office 'where the action is'.

Manning indicates that to deal with the foregoing issues, Control Data Corporation provides nearly all participants in its 'alternate work sites' programme with both a central office location (consisting of meeting rooms, pick-up and delivery stations for work assignments, mail boxes, and lockers) and an alternate work site. More than half of the work assignments are completed at these decentralized offices. In addition, CDC tries to promote 'open and complete communication', offers workers regular opportunities to attend meetings at the central office, provides special educational programmes for skill development, and uses 'feedback mechanisms' to discuss individual and group performance. Clearly, CDC would not do these things if they were not necessary.

[68] *Op cit*, Ref 62.

[69] *Op cit*, Ref 64.

the organizations also may be able to shift or reduce fringe benefit costs. However, this is likely to be only a temporary advantage, if it occurs at all. The price for contract and piece work will eventually be adjusted to include fringe benefits where not initially included by the unwary.

(6) The major disadvantages for organizations involved in teleworking relate to the management and supervision of the workers. To the extent that work can be parcelled out on a project or piece basis with a fixed cost attached, this problem is ameliorated; to the extent it cannot be so parcelled out, or employee productivity otherwise measured, supervision is made more difficult.[70]

Summary

The prospect that telecommunications might constitute a substitute for transportation, thereby resulting in energy conservation, remains just that – a prospect. Increases in energy conservation that might result from telecommunications substitution for transportation are difficult to predict. Reasonable estimates of such savings range from 1 to 3% of total energy consumption, or up to 5% of total petroleum consumption. But, the margin of error in these estimates is at least as large as the estimated energy savings, due to the problematic assumptions and data on which the estimates are based.

Moreover, the real potential of telecommunications as a substitute for travel also remains difficult to predict. While attitudinal research shows that potential substitutability of 20 to 30% exists, the operational studies to date have failed to clearly demonstrate that travel reduction or travel avoidance has occurred with existing telecommunications systems. One reason for the poor performance relates to the relatively slower rate of diffusion of telecommunications technologies than had been anticipated earlier. For example, Johansen, Hansell and Green[71] recently wrote that teleconferencing:

> . . . has not yet been implemented on anything like the scale anticipated in the early 1970s. Certainly teleconferencing has been successfully used by some organizations . . . Mostly, though, teleconferencing consists of vague promises, often the same promises that were made 10 years ago.It sometimes seems as though nothing has been learned over the past decade, that many of today's promoters of teleconferencing are merely restating old – and largely unfulfilled – promises.

And teleworking, the natural child of the teleconferencing idea, seems to have fared no better during the past decade than its parent.

The research clearly suggests that while telecommunications technology might yet substitute for travel, it will not happen quickly, and probably will not happen without changes in attitudes, behaviour, technology, and economics. These factors, which influence individual and organizational users' decisions about whether to substitute telecommunications for travel, are examined in Part II of this article.[72] Also examined are major views of the government's role in relation to increased use of telecommunications for achieving energy conservation, and specific mechanisms of government policy for affecting telecommunications substitution.

[70]Olson summarizes the problem nicely as follows: 'From management's point of view, the primary problem with telework is how to supervise people who are out of sight. Many managers I have spoken to feel it is not feasible unless a job has measurable outputs, even though comparable measures are often not necessary for in-house personnel performing the same jobs. Thus, acceptance of the idea by management will probably not come before either output measures are developed (possibly indexed to compensation) or fundamental changes in management attitudes take place'. (Personal communication from Margrethe Olson, 5 October 1981).

[71]R. Johansen, K. Hansell, and D. Green, *Teleconferencing Growth: Looking Beyond the Rhetoric of Readiness*, Institute for the Future, Menlo Park, CA, 1981, p 1. See also Robert Johansen, Kathleen J. Hansell and David Green, 'Growth in teleconferencing: looking beyond the rhetoric of readiness', *Telecommunications Policy*, Vol 5, No 4, December 1981, pp 289–295.

[72]To be published in *Telecommunications Policy*, June 1982.